

The use of urban wood waste as an energy resource

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Abstract. The capabilities use of wood waste in the Ekaterinburg city, generated during the felling of trees and sanitation in the care of green plantations in the streets, parks, squares, forest parks was investigated in this study. In the cities at the moment, all the wood, that is removed from city streets turns into waste completely. Wood waste is brought to the landfill of solid household waste, and moreover sorting and evaluation of the quantitative composition of wood waste is not carried out. Several technical solutions that are used in different countries have been proposed for the energy use of wood waste: heat and electrical energy generation, liquid and solid biofuel production. An estimation of the energy potential of the city wood waste was made, for total and for produced heat and electrical energy based on modern engineering developments. According to our estimates total energy potential of wood waste in the city measure up more 340 thousand GJ per year.

1. Introduction

In Russia, the problem of utilization of wood waste in the forestry and woodworking industry, as well as wood waste generated during pruning trees and bushes on city streets and park zones, is one of the most urgent. It is so because at present more than a half of the tree biomass is lost with the existing methods of processing. But in the cities at the moment, all the wood waste is brought to the landfill of solid household waste. It indicates a low level of technological processes of woodworking and ignoring existing opportunities for using wood waste from cities.

Wood waste can be used as an energy resource to provide the urban consumer with heat and electrical energy. Such an approach will improve environmental performance by reducing the waste amount at urban landfills and production of useful energy from renewable sources of wood waste.

2. Research area – Ekaterinburg city

Ekaterinburg – one of the largest economic centers of the world, is on the list of City-600, compiled by the research organization Mc Kinsey Global Institute. Ekaterinburg is located in a zone moderately a continental climate, so characterized by sharp variability of weather conditions with pronounced seasons. According to the landscape zoning the city is located within the south-taiga forest zone, near its boundary with the subzone of mixed forests [1].

The vegetation cover of the city is represented by native south-taiga aspen, birch and pine forests, and grown on site cutting down the aspen-birch forests; and flooded meadows, tree and shrub thickets, vegetation along the on the coasts of transitional sedge-sphagnum marshes (on the city outskirts). In general, urban vegetation is characterized by high floristic wealth. Pine trees, birches, rare and relic plants grow on the territory of the Shartash forest park and in the mountains of Uktus.



The greening system in Ekaterinburg was formed over two centuries. It was influenced both by natural factors (location within the city of natural forests, mostly coniferous), and urban planning. The main stages of development: the beginning of the XIX century characterized by private, manor gardening; the end of XIX – the beginning of the XX century, the appearance of the first public landscaping objects (boulevards, a square on an urban dam, Weiner Garden and Kharitonovsky Garden); the second half of the twentieth century – the expansion of forestry functions.

The modern stage of the city planting is characterized by the compacting of the building, as a result the gardening area in the residential zone is reduced. The city has a rather tense ecological situation, conditioned by air pollution. High rates of construction lead to a reduction of some parked massifs area. The provision of green plantations in recent years is kept at the level of 17 square meters per person [2].

According to the city administration, in 2015 the area of green plantations of common use was 24 544 ha, the parks, boulevards and squares area – 2493 ha [3]. Planted trees and shrubs in the amount of 28 279 pieces in 2015. The total volume of waste entering municipal landfills in the same year amounted to 554 thousand tons.

Morphological composition of waste in cities, which collected to landfills is shown in Figure 1.

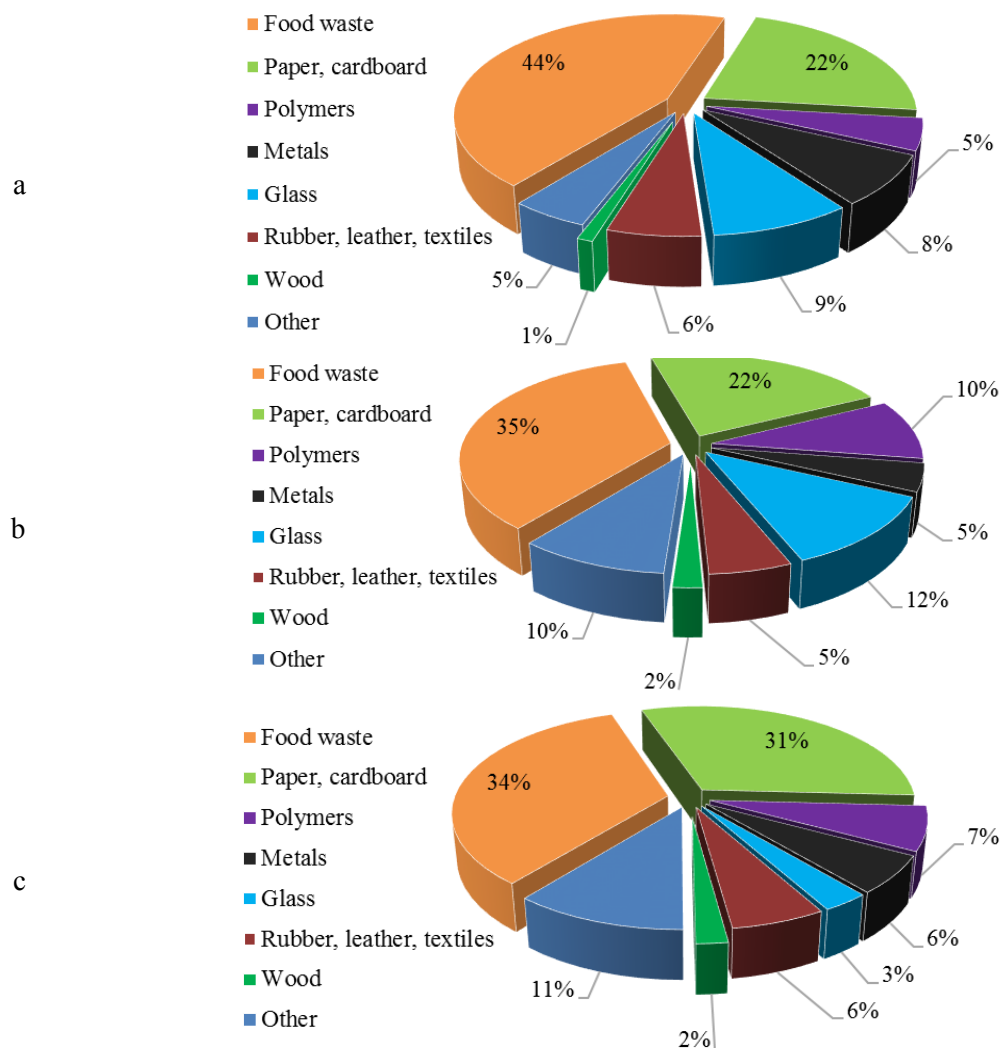


Figure 1. Morphological composition of waste in cities:
a – Nizhnevartovsk [4], b – Kiev [5], c – Ekaterinburg

For comparison, take the city:

- a) Nizhnevartovsk (population 271 thousand people, 61° N, area 271.3 km²), located in the Sredneobsk lowland of the West Siberian Plain in the middle reaches of the Ob River on its northern coast;
- b) Kyiv (population 2 927 thousand people, 50° N, area 847.7 km²), located in the center of Eastern Europe on the Dnieper River;
- c) Ekaterinburg (population 1 456 thousand people, 56.5° N, area 468 km²), located on the eastern macroslope of the Middle Urals, along the coasts of the Iset River.

In the municipal economy at the moment, all the wood that is removed from city streets, parks and squares is brought to the landfill of solid household waste, that is, it turns into waste completely. According to the information of the organization MUE "Zelenstroy", which deals with the trees cutting, sorting and evaluation of the quantitative composition of wood waste is not carried out.

Figure 2 are shows photographs of the pruning process of woody and shrubby vegetation on the streets of Ekaterinburg.



Figure 2. Pruning trees and shrubs in the streets of Ekaterinburg

According to the municipal program "Improving the improvement of the territory of the municipality city of Ekaterinburg for 2017–2020" (Decree No. 2353 of 29.11.2016) [6] the purpose of the subprogram "Improvement and gardening of the territory of the municipality city of Ekaterinburg" is the organization of improvement and landscaping of the territory of the municipality, use, conservation, protection reproduction of urban forests and forest areas, are located within the boundaries of the municipality. The plans for 2017–2020 increase the number of planted trees and shrubs by 470 pieces per year, which will provide an average growth in wood material from 140 m³ per year.

3. The situation in foreign countries

The total wood stock in Russia reaches almost 82 billion m³. This is four times more than in the US, forty times more than in Sweden and sixteen times more than in Finland. The volume of wood waste

in the domestic forest industry is proportionally potentially much higher. According to experts' estimates, it is technically possible to use up to 800 million tons of wood biomass annually in Russia for energy purposes only [7]. Almost all developed foreign countries have a common approach to integrated wood processing, including waste use [8].

The proportion of forest area in relation to the total area in northern European countries [9], with a high degree of urbanization of the population from 76% in Norway to 92% in Iceland similar in terms of climatic conditions and type of terrain to Ekaterinburg, is shown in Figure 3. This comparison is possible because the authors [9] consider define urban woodland as located in close to urban agglomerations.

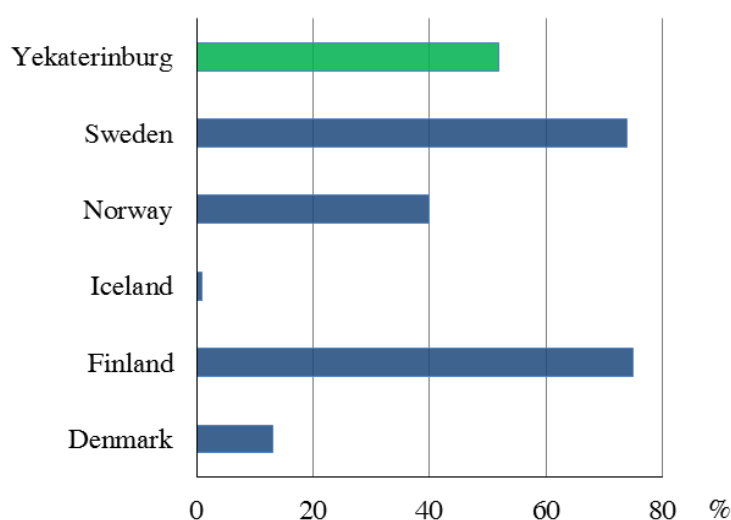


Figure 3. Area of forest and other wooded land

More complete use of wood in the US was made possible through the introduction of debarking machines and chippers, to produce clean chips of higher quality (without bark). In Canada, the bulk of waste is used in the production of pulp, with one quarter of sawdust due to the introduction of the continuous pulping process. In Sweden, wood chips (about 60%) prevail among the wastes, which compose the raw material base for the production of fiberboard and chipboard. In Finland, more than 85% of waste is consumed in the pulp and paper industry [8]. In Norway, in equal shares waste is directed to the production of plates and pulp.

Foreign companies in Germany, Austria, Finland and other countries offer equipment for the energy use of wood waste to generate heat and electrical energy.

The countries with the highly developed sawmilling and woodworking industry, for example, the USA, Canada, Japan and the countries of Northern and Central Europe, achieved the greatest results in the use of wood waste.

4. Energy use of wood waste

In large cities, it is a problem to the utilization of wood waste, generated during the felling of trees and sanitation in the care of green plantations in the streets, parks, squares, forest parks, etc. These waste are a low-quality wood of medium size, e.g. boughs, twigs peaks, bark fragments of coniferous and hardwoods.

In the greening of urban areas, green spaces are being reconstructed. It is a complex of agro-technical activities for replacing diseased and shrinking trees and shrubs, improving the species composition, and pruning woody and shrubby vegetation. Sawn trees and wood waste formed during pruning are exported by organizations that are engaged pruning branches in crowns and the removal

of deadly, accidental trees that have lost their decorative value. The average composition of waste when cutting a tree [10] for minimum and maximum values is given in Figure 4.

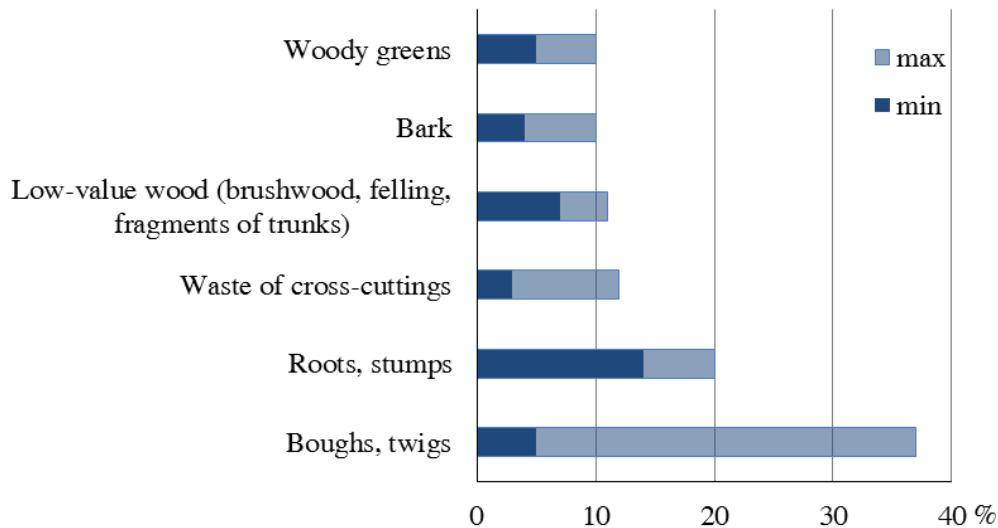


Figure 4. The specific waste composition of a sawn tree

The values of the lowest energy of wood waste combustion [11] are shown in Figure 5.

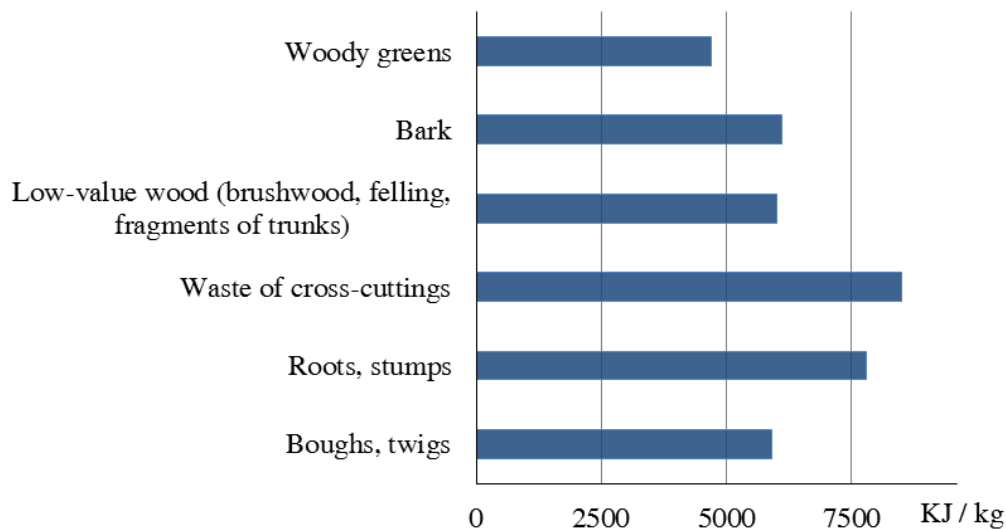


Figure 5. Lowest calorific value of wood processing waste

Figure 6 shows scheme of possible methods for the energy use of wood waste. In addition to waste disposal in landfill, technical solutions exist for converting them into heat and electrical energy, as well as into other types of products (pellets, briquettes, synthetic biofuels, etc.).

Wood waste can be used as fuel, for example sawdust and bark to increase the calorific value are briquetted. In this case, the calorific value of dry briquettes is much higher than that of raw sawdust, and wood pellets produce more heat energy in the process of burning.

Boilers on wood waste are designed to produce heat energy in the form of steam and (or) hot water by burning the crushed wood. Boilers of this type include a fuel bunker, a device for transporting waste to the combustion chamber, which can provide continuous and periodic fuel supply [12], a solid fuel boiler, ash removal equipment, chimneys equipped with a combustion gas purification system,

an automated control and safety system, also other units and systems. The pellet as fuel are increasingly used in boilers at the present time [13]. The received thermal energy can be used for maintenance of the industrial enterprises, social objects or household consumers.

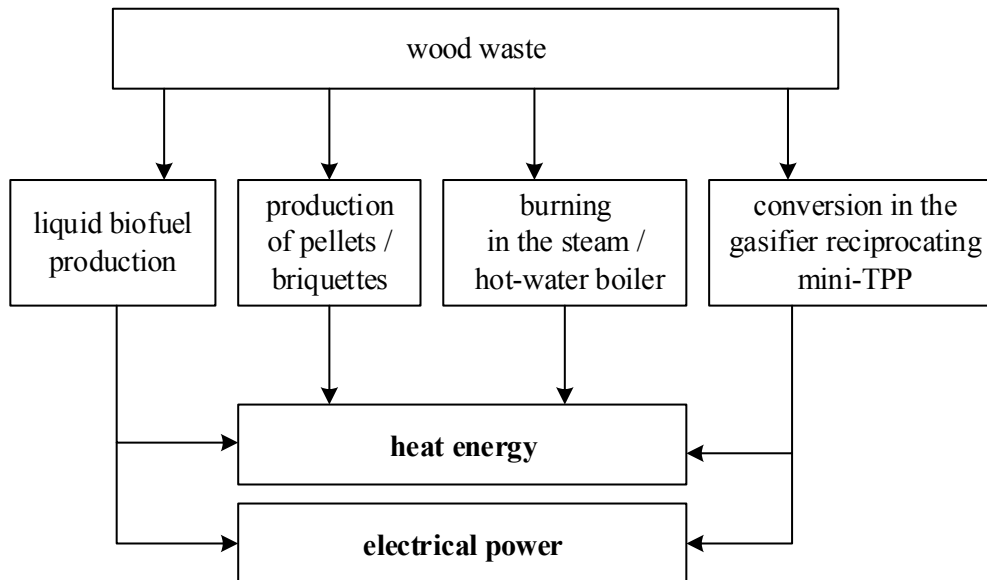


Figure 6. Possible ways of energy use of wood waste

The effective conversion of wood waste including bark is possible with using the gasification plants, which allows to have in addition to energy a significant amount of associated technological products [7]. In the world, technological solutions are also used to gasification wood waste with the generation of heat energy and electricity when the synthesis gas is fed into the internal combustion engine. The article [14] compares different gasification plants, e.g. two stage [15] and the one stage method of the gasification, that use biomass as a fuel. In their experiments the authors were able to get gas with a calorific value of dry gas (LHV) 4.64–5.33 MJ/Nm³.

In the work [16] the theoretical results obtained using the engine's mathematical model are also in a satisfactory agreement with experimental data obtained on the engine as a part of investigations of coupled modelling and experimental research of the gasifier and the engine as a whole biomass energy system.

If are comparing the gasification and combustion of wood waste, it may be noted most gasification efficiency for small capacity plants for electrical power generation, since in the same time also heat energy is produced as well as in boilers.

The questions of costs for transporting wood waste to power installations in the general economic evaluation of their energy use in this case do not arise. The costs of wood waste transporting exist and when cutting down tree plantations are transported for disposal at the landfill. Thus, the total costs of shipping waste to the site energy recovery are equal to those that are available in the process of cutting down tree plantations and its transportation to the landfill.

The energy potential calculation of the wood waste in the Ekaterinburg city for 2015 by types of produced fuel and energy sources should begin with an estimate of the total energy potential (GJ) of wood waste [11], which is determined by the equations:

$$E_{ww} = m \cdot Q_i^r \cdot 10^{-3} \quad (1)$$

m – potential resource (mass) used type of wood waste, t;

Q_i^r – lower calorific value of wood waste on the working mass of fuel, MJ/kg.

Based on the technology for heat energy production described above, is determined the quantitative potential of the heat energy generated from waste taking into account the efficiency of the boiler according to the following formula:

$$Q_b = E_{ww} \eta_b \quad (2)$$

η_b – efficiency of the plant for wood waste burning (boiler water).

The amount of electrical energy produced from wood waste during their gasification with further combustion of synthesis gas in the internal combustion engine is defined as:

$$W_g = E_{ww} \eta_{gf} \eta_{ICE} \eta_{eg} \quad (3)$$

η_{gf} – efficiency of gasifier;

η_{ICE} – efficiency of internal combustion engine;

η_{eg} – efficiency of electric generator.

In addition to electric power, such a plant can provide consumers with heat energy together, that is, it work in the cogeneration cycle. When transferring the obtained values into GCal for heat and in MWh for electric energy, are obtained the final values given in Table 1.

Table 1. Annual energy potential of wood waste in the Ekaterinburg

Type of energy source	Units	The resulting value
Wood waste	GJ	341 825
Heat energy	GCal	71 894
Electrical power	MW·h	23 798

Equally important is the ecological aspect of the problem, wood fuel is practically sulfur-free and has a high reactivity. Therefore in exhaust gases by burning wood there is no sulfur dioxide and sulfur gas, and the carbon monoxide content with rationally designed combustion devices is minimal. In the same way, wood is considered to be CO₂ neutral fuel, because of the carbon dioxide is captured in the process of wood growth, and when sawed wood is used for energy production, the same amount of carbon dioxide is produced per kilogram of material as when it landfilled.

5. Conclusions

In the Ekaterinburg city there is a program for improvement and gardening of the territory of the municipality by planting more trees and shrubs. But, at the same time resources of wood waste, generated during the felling of trees and sanitation in the care of green plantations in the streets, parks, squares, forest parks are not being used, and a technologies for useful disposal are not being worked out now. In the municipal economy at the moment, all the wood that is removed from city streets, parks and squares is brought to the landfill of solid household waste, that is, it turns into waste completely.

The capabilities use of wood waste in the Ekaterinburg city was investigated in this study. According to our estimates total energy potential of wood waste city measure up more 340 thousand GJ per year. In addition to waste disposal in landfill, technical solutions exist for converting them into heat and electrical energy, as well as into other types of products (pellets, briquettes, synthetic biofuels, etc.).

To improve environmental in the site and production of useful energy, the wood waste can be used as an energy resource. The calculated potential of wood waste in Ekaterinburg to provide the urban consumer with heat energy is 71 894 GCal, and electrical energy is 23 798 MW·h per year. This use of wood waste renewable sources can reduce the waste amount at urban landfills.

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